

# *Introduction*

**On February 18<sup>th</sup> 2005 D0 Spokepersons asked Dmitri Denisov, Gaston Gutierrez and Marvin Johnson to review D0 luminosity measurement status and provide recommendations on such issues as dead time corrections, luminosity system performance and issues related to measurement of the luminosity at  $L > 100 E_{30}$ .**

**From February 18<sup>th</sup> to March 11<sup>th</sup> the Committee with help from luminosity group studied available documentation as well as performed measurements with existing D0 luminosity system. The results of these studies as well as Committee recommendations are presented in this report.**

**The Committee would like to thank Rich Partridge, Brendan Casey and Tim Andeen for their cooperation and help during review process.**



## ***Recommendations: short term***

- **Check and eliminate loose cables, bad terminations and improve labeling of cables and modules.**
- **Optimize CFD discriminator output width, FastZ reset width and FastZ timing to minimize FastZ dead time correction.**
- **Put the dead time correction for the D0 luminosity measurement as proposed in the D0 Note 4710 online.**



## ***Recommendation: medium term***

- **Obtain numbers on PMT aging due to long term operation with large anode current. Estimate lifetime of the PMTs, if operated on the plateau, and plan to increase PMT HV as to attempt to run every PMT on the plateau.**
- **Consider the possibility of replacing the linear fan in, amplifiers and coupling capacitors with a CFD discriminator for every channel. This will reduce noise, eliminate the base line shift, eliminate the saturation of the linear fan ins, facilitate running the counters at higher voltages providing at least the same time resolution.**
- **Consider installation of a time histogrammer. This will allow for 1) improved estimation of the halo, 2) monitoring of the FastZ module.**
- **Estimate change in the luminosity constant based on HV adjustments, magnetic field change, changes in the electronics designed to reduce effect of baseline shift and dead time correction. If the correction is more than 6.5% implement hardware changes and luminosity constant change (newly obtained) concurrently.**
- **Add monitoring for each individual counter channel. This will allow detection of problems with the counters, PMTs, discriminators timely.**



## ***Recommendation: long term***

- **Study alternatives to counting zero for measuring luminosity above  $150E30$ . The current system might not work for  $L > 150E30$ .**



# ***Recommendation: general***

- **Substantially increase the manpower devoted to the luminosity system.**



# *A feeling for what we are up to*

**Estimate for an error in luminosity measurement:**

$$P(0) = e^{-\mu} \Rightarrow \frac{\Delta P(0)}{P(0)} = -\mu \frac{\Delta \mu}{\mu} = -\mu \frac{\Delta L}{L} = -0.01 \mu$$

**For 1% error in L, we can not miscount more than 3 zeroes per million interactions.  
The following numbers are calculated with an inelastic cross section of 60.7 mb.**

Initial luminosity (in 1E30)	Average # of interactions per crossing	Probability of zero per crossing	Error in P(0) for a 1% error in luminosity
10	0.35	0.70	0.3 %
20	0.71	0.49	0.7 %
60	2.1	0.12	2.1 %
100	3.5	0.029	3.5 %
Current record: 117	4.1	0.016	4.1 %
Expected in 2005: 140	4.9	7.1E-3	4.9 %
Expected in 2006: 200	7.1	8.7E-4	7.1 %
Design (2008): 290	10.2	3.6E-5	10.2 %



# *D0 vs. CDF luminosities*

## Appendix 1

The studies shown in the following 4 transparencies indicate that:

- The PDT currents are linear with CDF luminosity.
- The PDT currents are only linear with D0 luminosities up to about  $L=60E30$ , then they start to deviate.
- Up to about  $L=40E30$  the D0 luminosity is about 6-11 % lower than CDF's.
- On February 28 the CDF/D0 ratio changed from 7 to 11 % when cables were wiggled. We don't understand the change on February 25<sup>th</sup>.
- The discrepancy between D0 and CDF luminosities increases to about 20% at  $L=100E30$ .



# *PDT currents vs. time and luminosity for store 3956*

8

PDT #

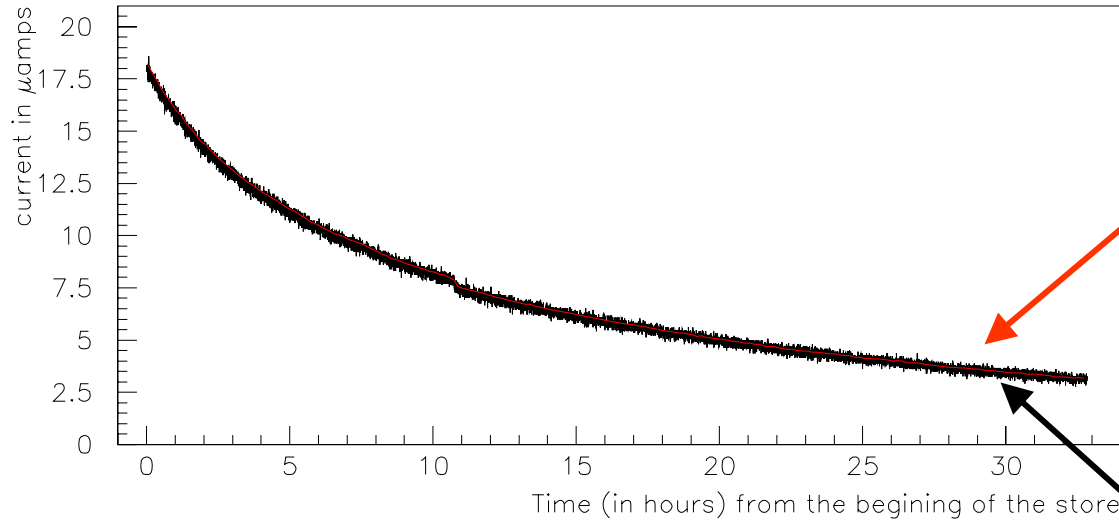


PDT currents for store 3956



Store 3956, 2-FEB-2005

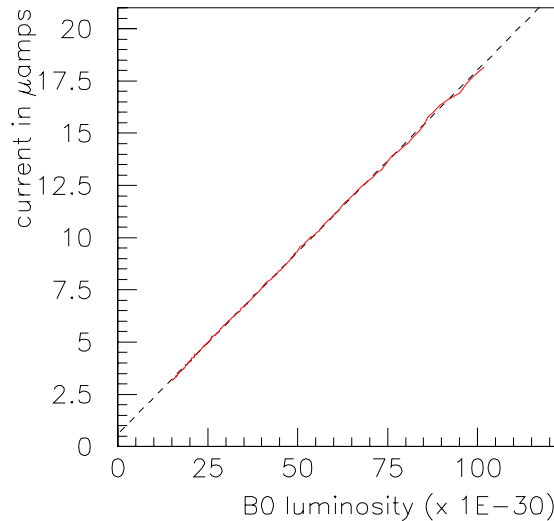
DW02, PDT= 013



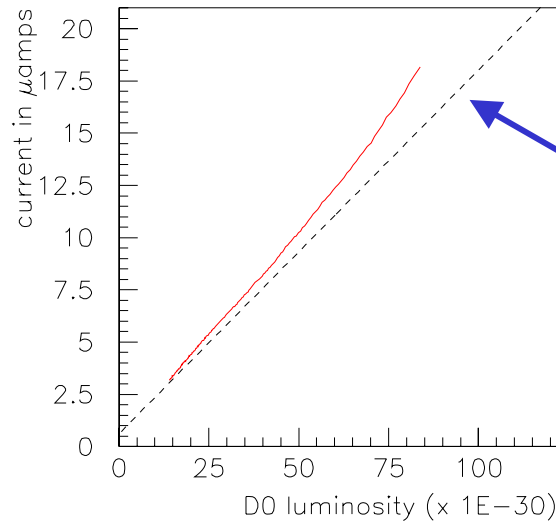
red line: current  
averaged every 10'  
(every lumi. reading)

black line: current  
(1 reading a second)

DW02, PDT= 013



DW02, PDT= 013



dashed line: fit  
to CDF plot



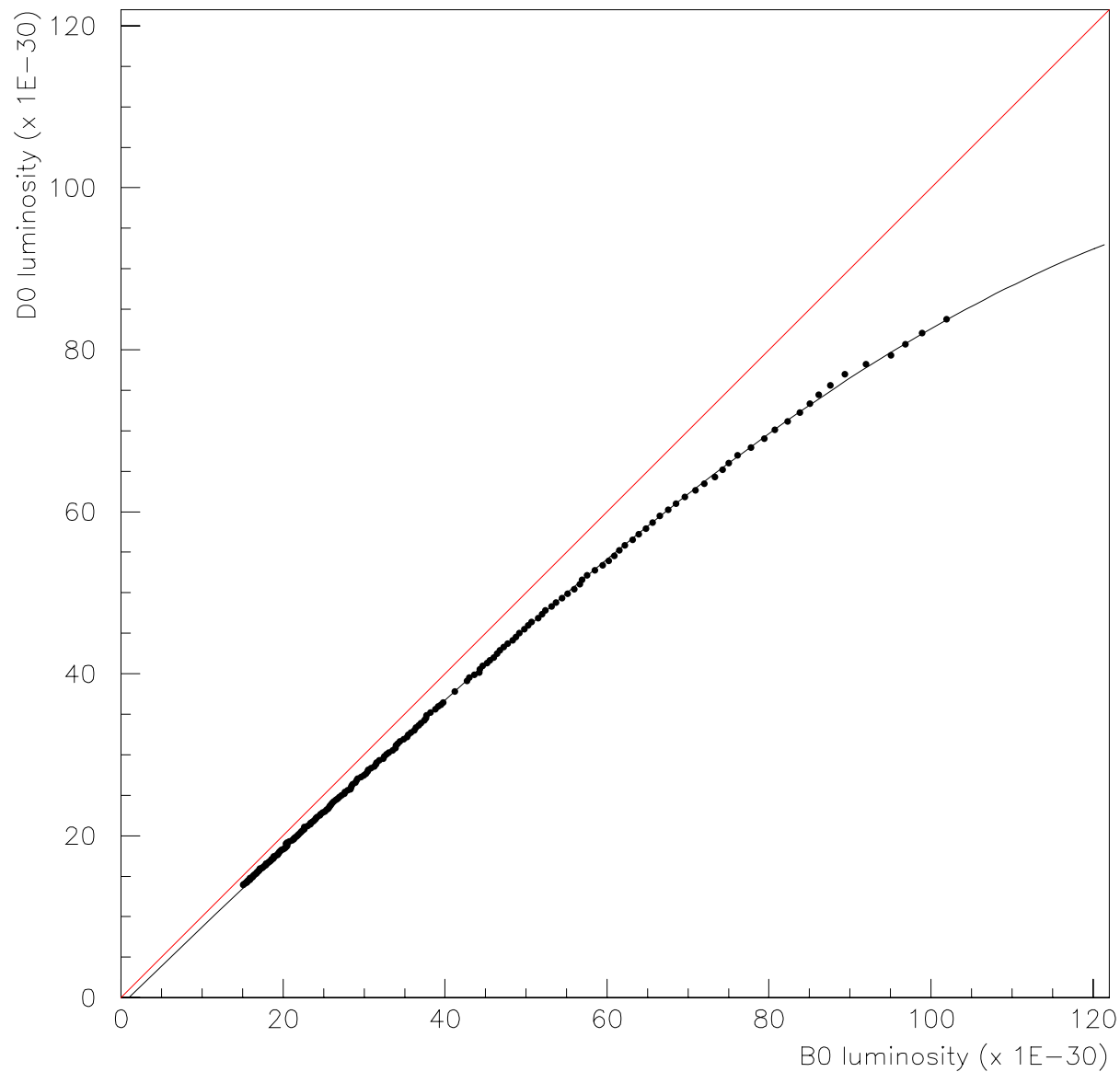
CDF



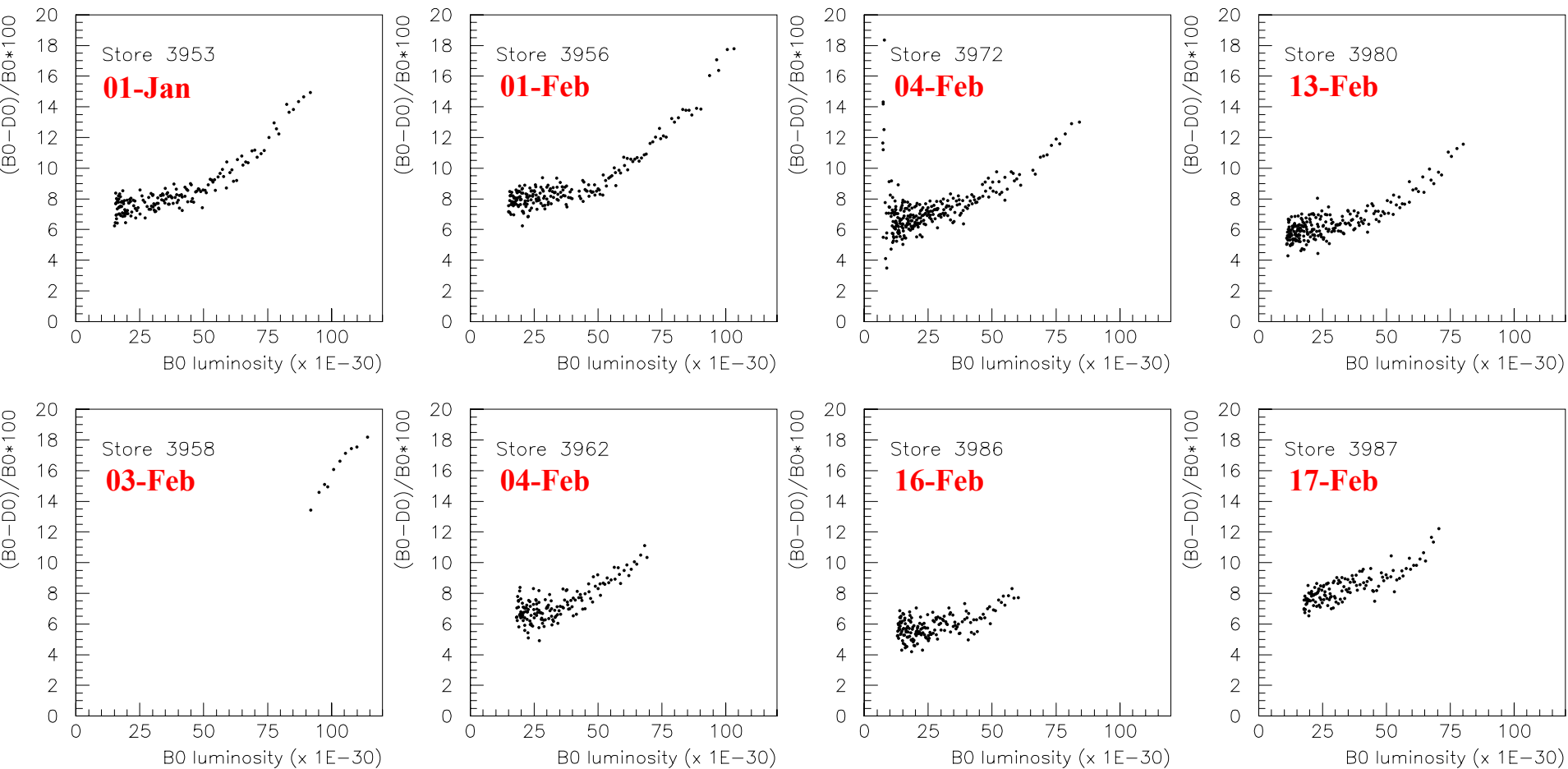
D0



# ***D0 vs. CDF luminosity for store 3956***

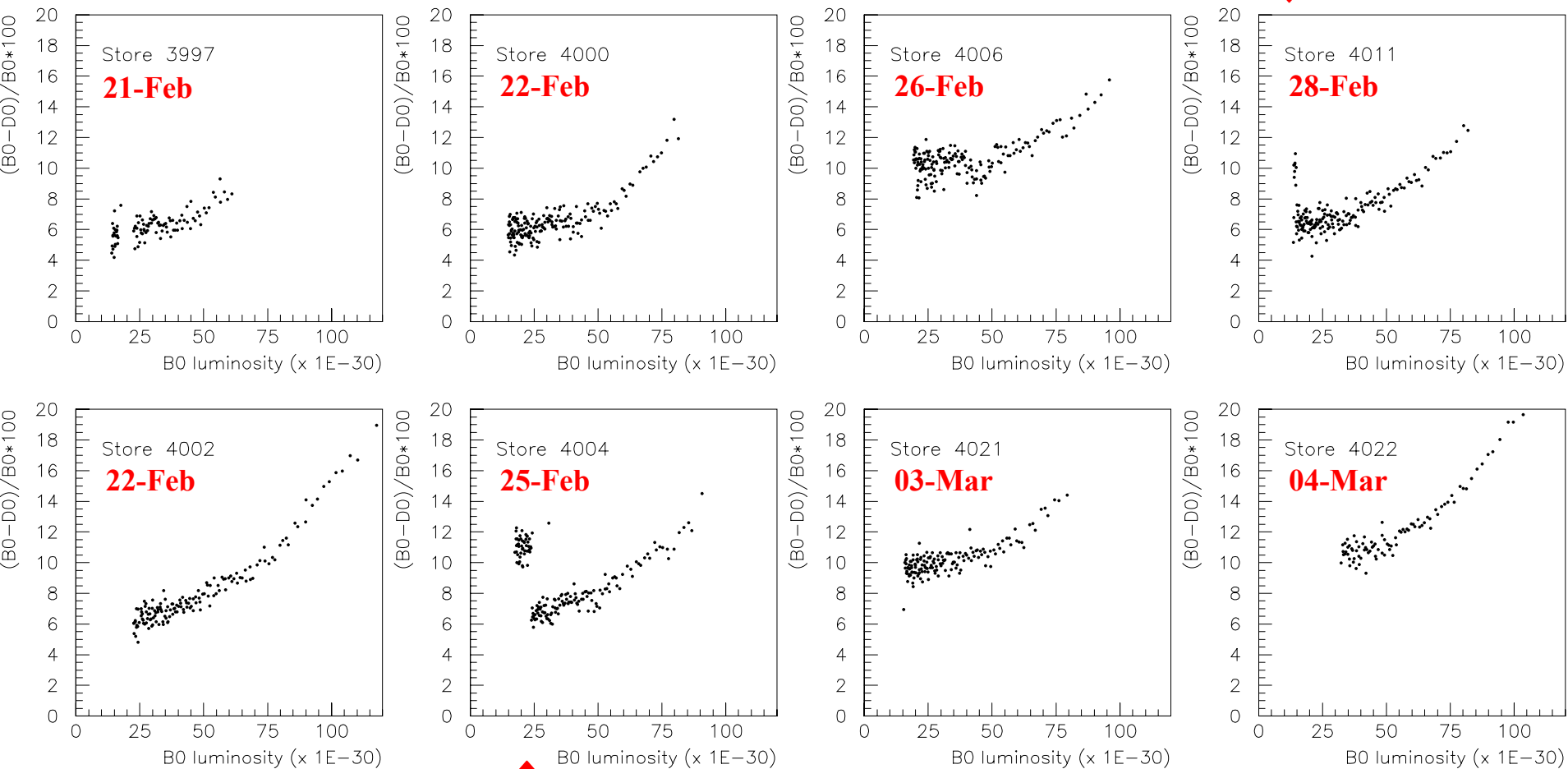


# *Luminosity ratio: $100x(1-D0/B0)$*



# *Luminosity ratio: $100 \times (1 - D0/B0)$*

**Jump in D0 luminosity produced by wiggling cables**



**Jump in D0 luminosity on 25-FEB at 22:07 hrs**



# *Counter's efficiencies*

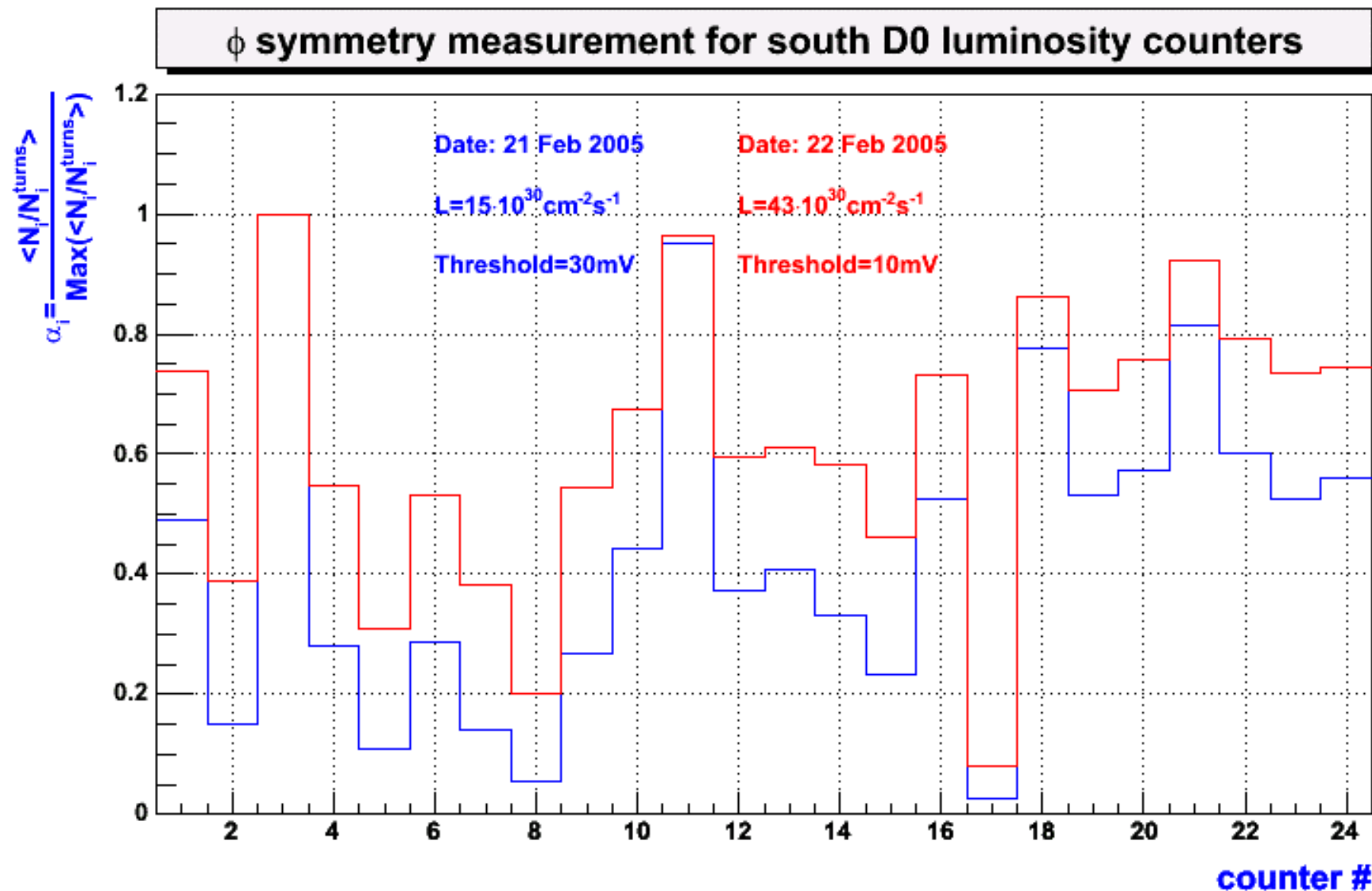
## Appendix 2

**The studies shown in the following 6 transparencies indicate that:**

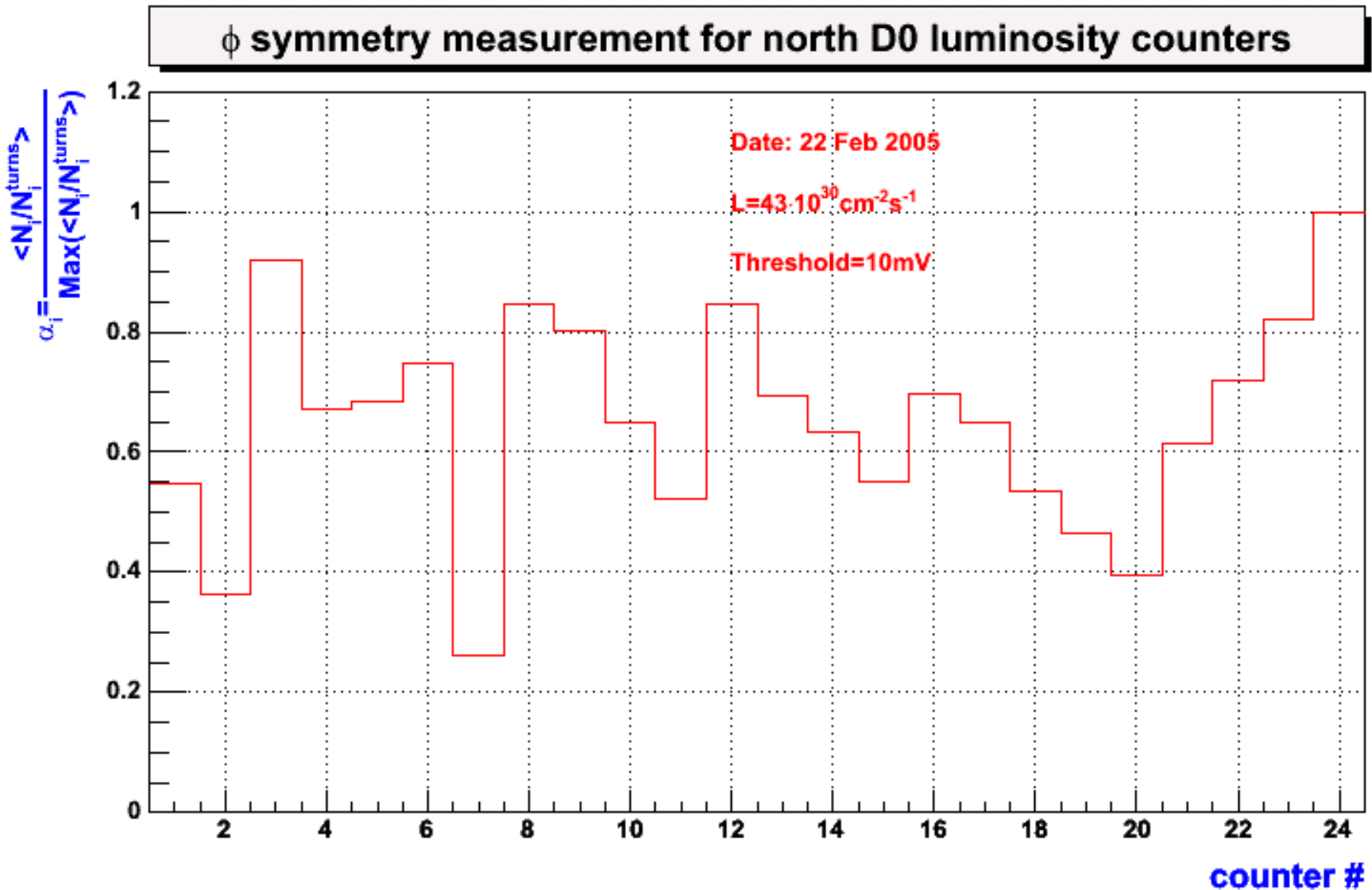
- There is a strong  $\phi$ -dependence in the counting rate of both the South and North luminosity monitors.**
- Most counters are operating at low efficiency. An estimate indicates that the average efficiency is about 20-30 %.**
- For low counter efficiencies the LM efficiency will depend strongly on the number of tracks in the event. Therefore different processes (HC, SD, and DD) will have different efficiencies.**
- There is room in the effective cross section calculation to account for changes in luminosity of several % for  $L < 60E30$ .**



# South counters $\phi$ -dependence with 10 and 30 mV thresholds

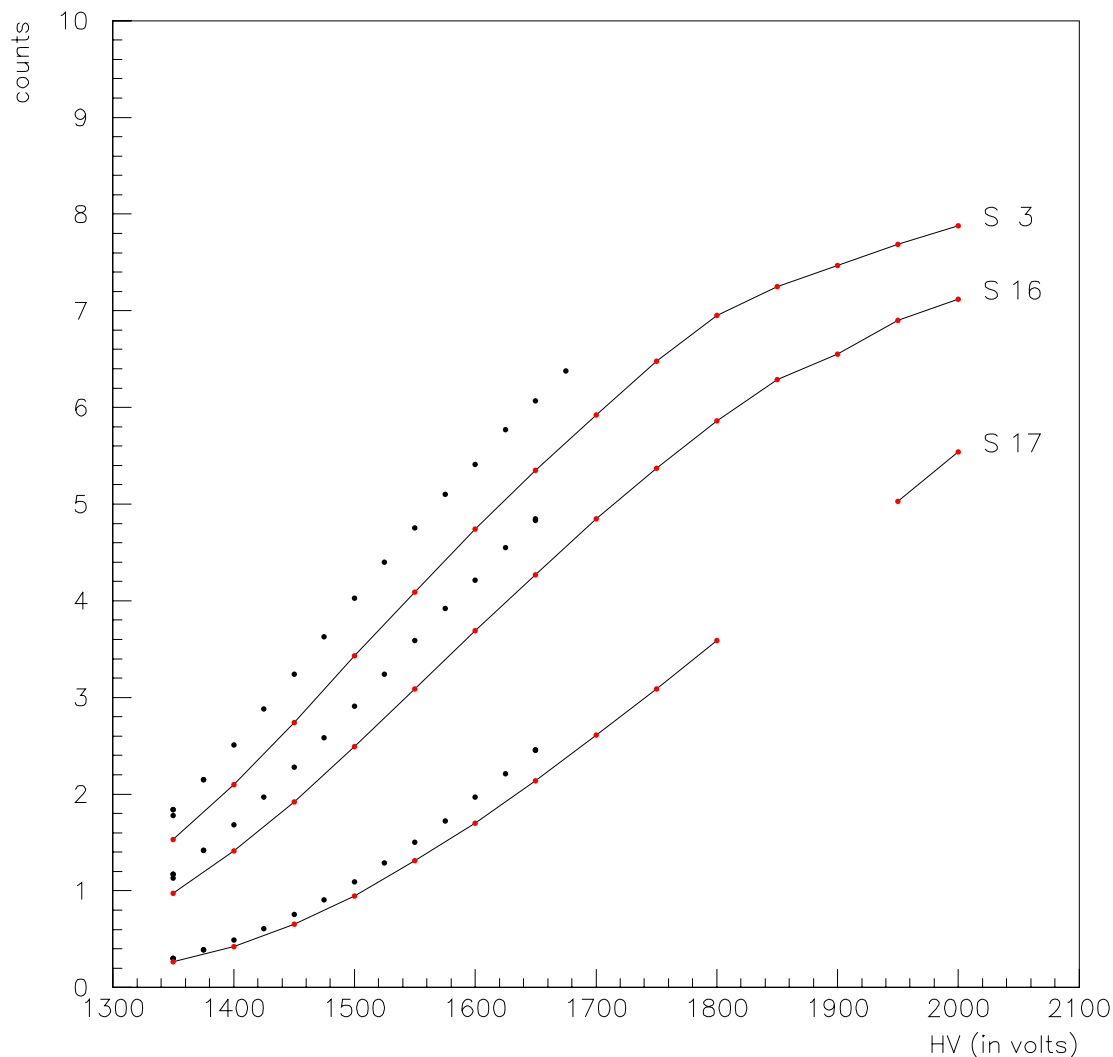


# North counters $\phi$ -dependence with a 10 mV threshold



# Counter rates as a function of HV

## Counts in 1E6 units



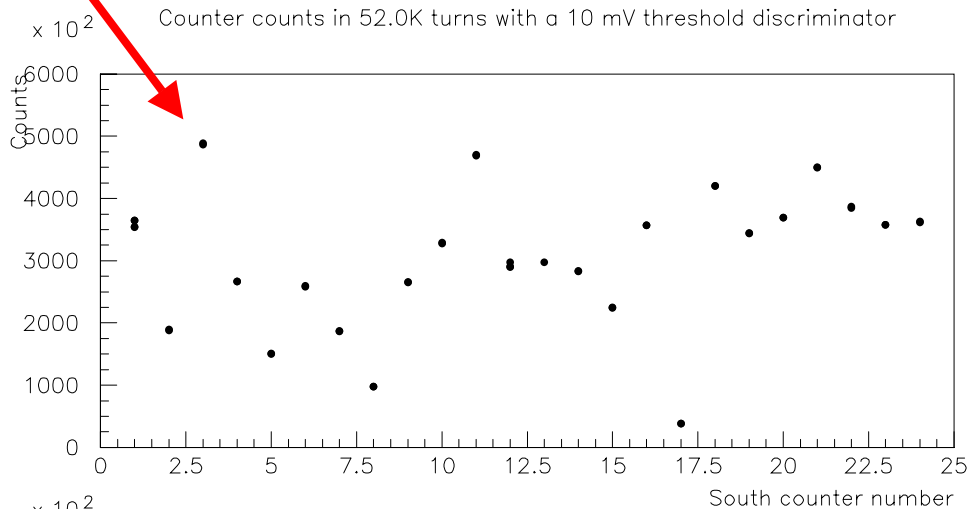
The black points are the first attempt to plateau the counters. We had to stop because we reached the HV limit imposed by the control system. The final measurement is given by the red points. They are lower because the luminosity had gone down. Hamamatsu specs are given at 2000 V.

Most counters operate at 1300 to 1500 Volts. The efficiency of counter S3 at nominal operating voltage is estimated at 40-45 %.

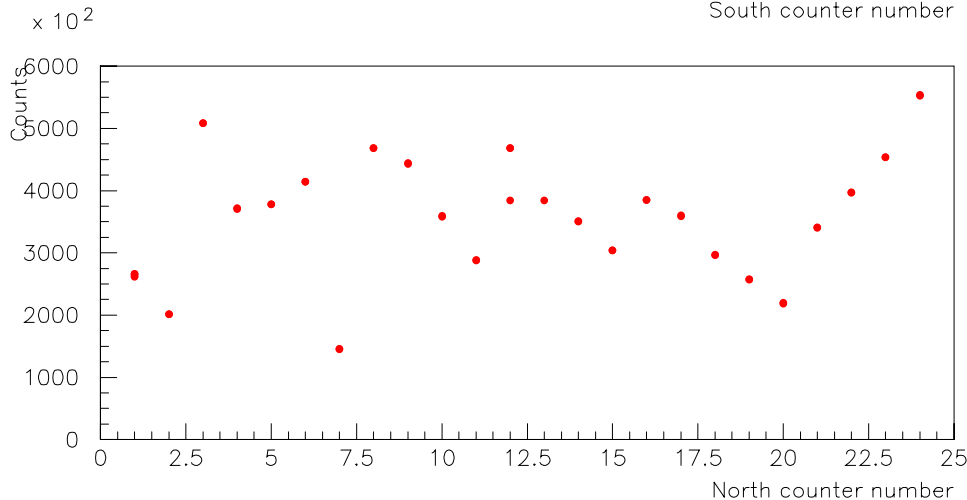


# Counter counts in 52.0K turns

**The efficiency for counter S3 is about 40-45 % (see previous page)**

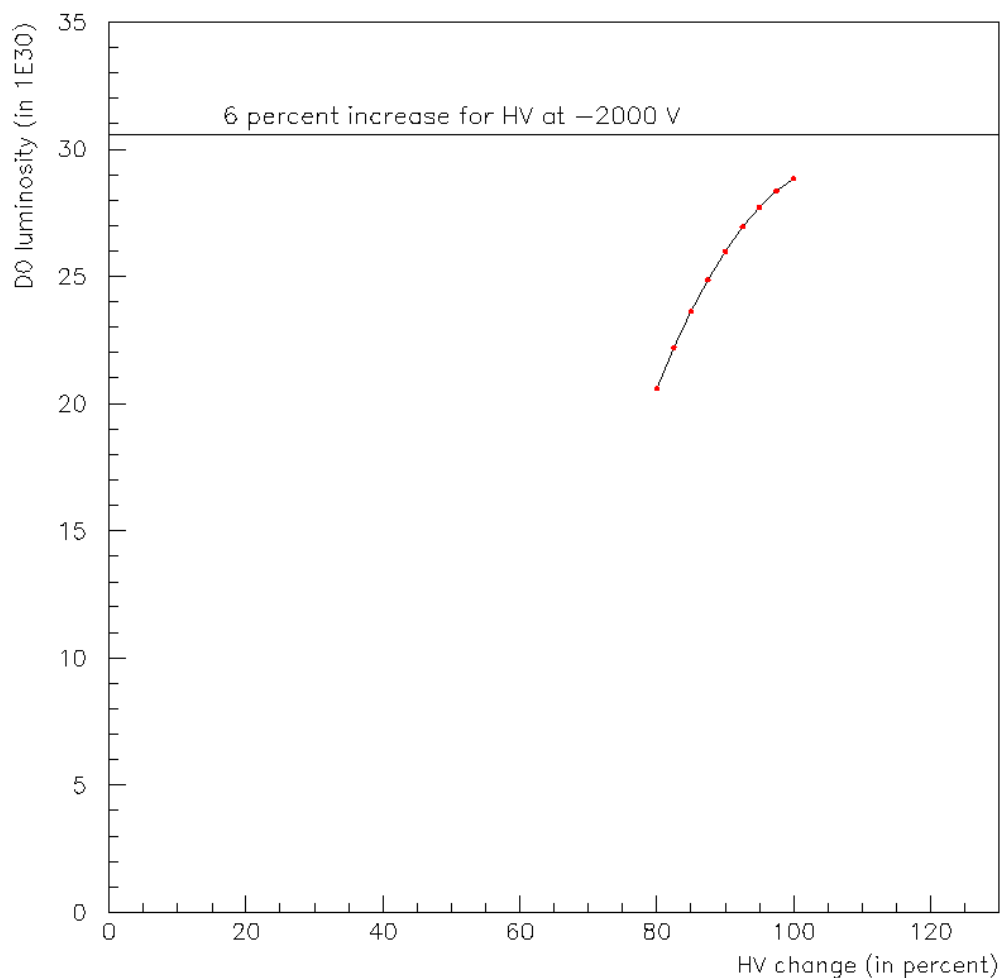


**Average per counter efficiency  
for South array ~ 20%**



**Average per counter efficiency  
for North array ~ 30%**

# *D0 luminosity as a function of HV*



**The following numbers are obtained by B. Casey:**

- 1. North counters array at 2000 V, South array at nominal, L increased by 5.6 %**
- 2. North counters array at nominal, South at 2000 V, L increased by 1.7 %.**
- 3. Both North and South at 2000 V, L increased by 6 %.**



# ***Luminosity Constant and Counters Efficiency***

**Fermilab-TM-2278-E describes luminosity constant calculations. Luminosity constant includes luminosity monitor efficiency of 90.9%. All classes of inelastic events (hard core, double diffractive and single diffractive) are combined in order to obtain this efficiency.**

**As different classes of events have different topologies (average number of particles created, etc.) and efficiencies of luminosity counters are substantially below 100% the calculation of the efficiency for luminosity constant has to be verified, especially for events with low multiplicities, like single diffractive events.**

**Increase in efficiency of luminosity counters, due to high voltage increase and/or extra amplification in combination with electronics threshold reduction will simplify process of luminosity constant calculation and reduce luminosity constant errors.**



## *Possible causes of dead time*

# Appendix 3

**The studies shown in the following 3 transparencies indicate that:**

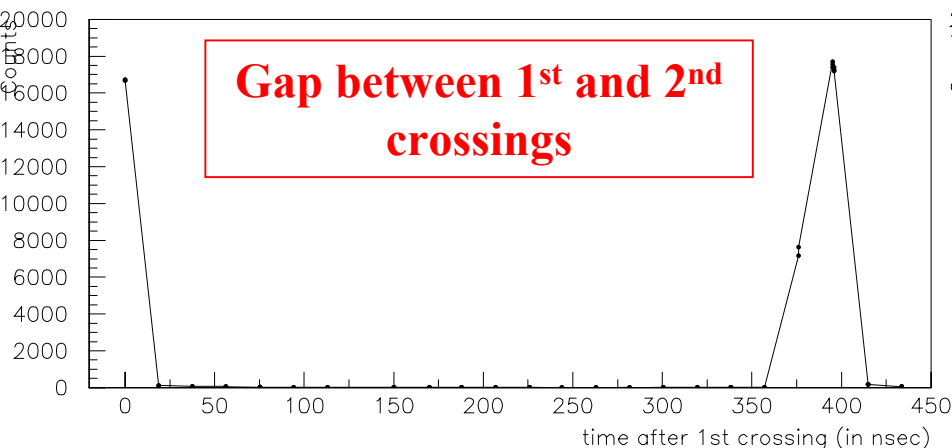
- **The activity in the gaps is about 0.1 %.**
- **Beam activation could account for a large fraction of the dead time. It would be desirable to have a detector immune to this problem.**



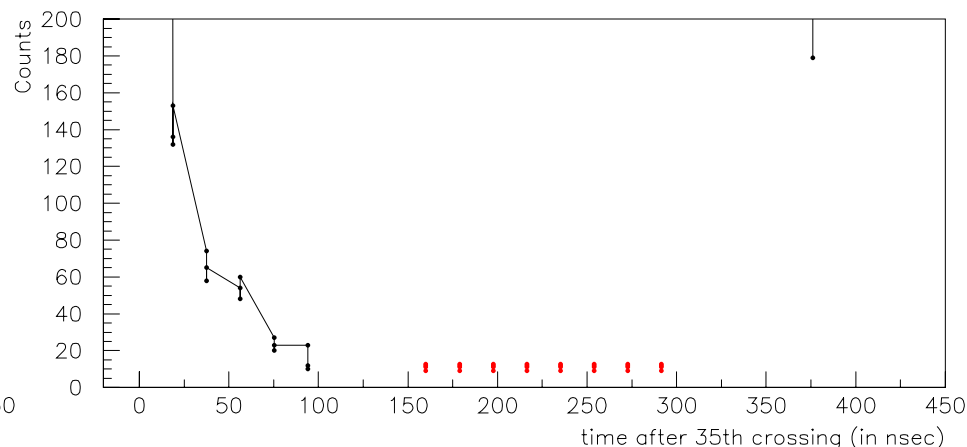
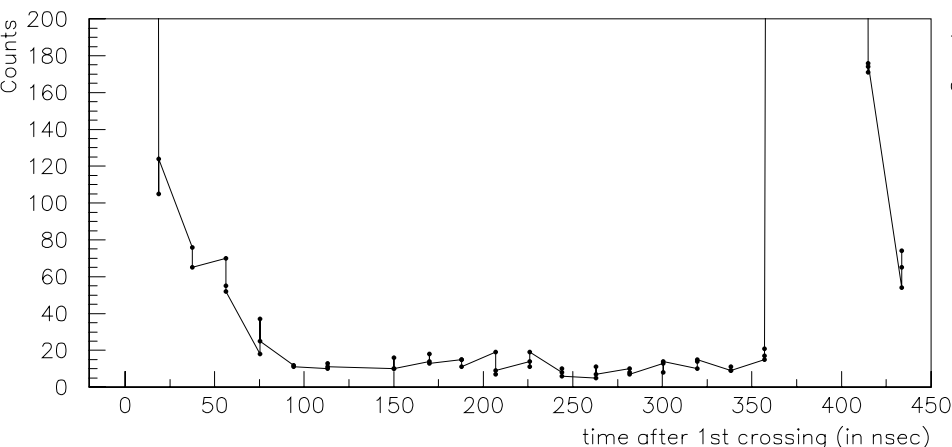
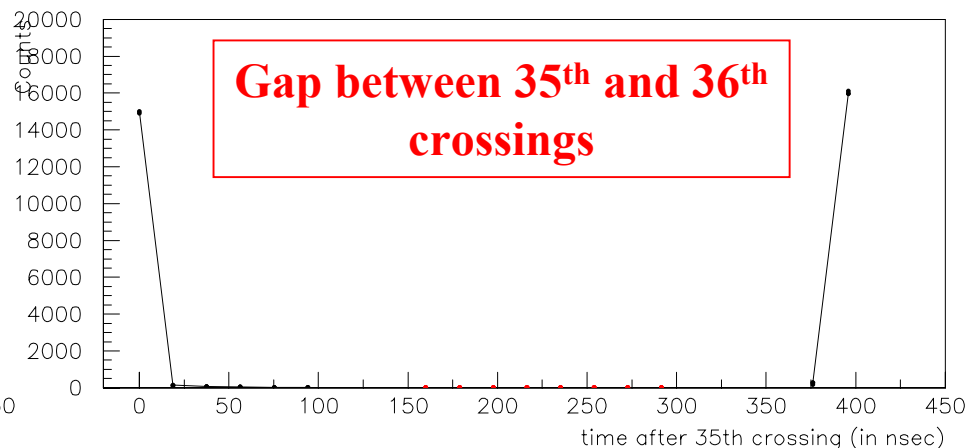
# Channel N24 rates after 1<sup>st</sup> and 35<sup>th</sup> crossings

Gate at 20 nsec for black points, and 164 nsec for red points. The counts with the 164 nsec gate were divided by 8.2 and repeated 8 times (to simulate the smaller steps)

Channel N24 counts within a 20 nsec gate for 52.0K turns



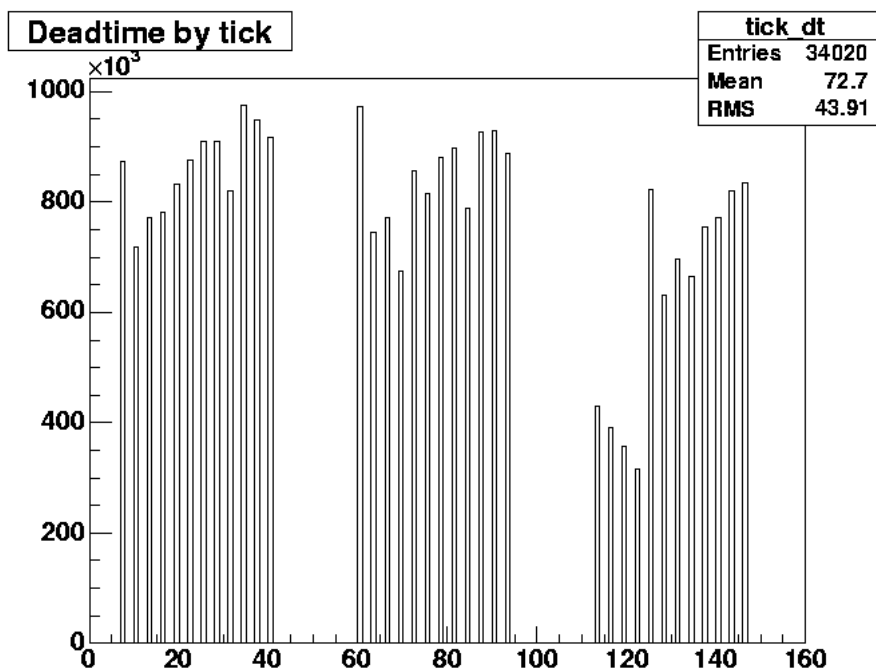
Channel N24 counts within a 20 nsec gate for 52.0K turns



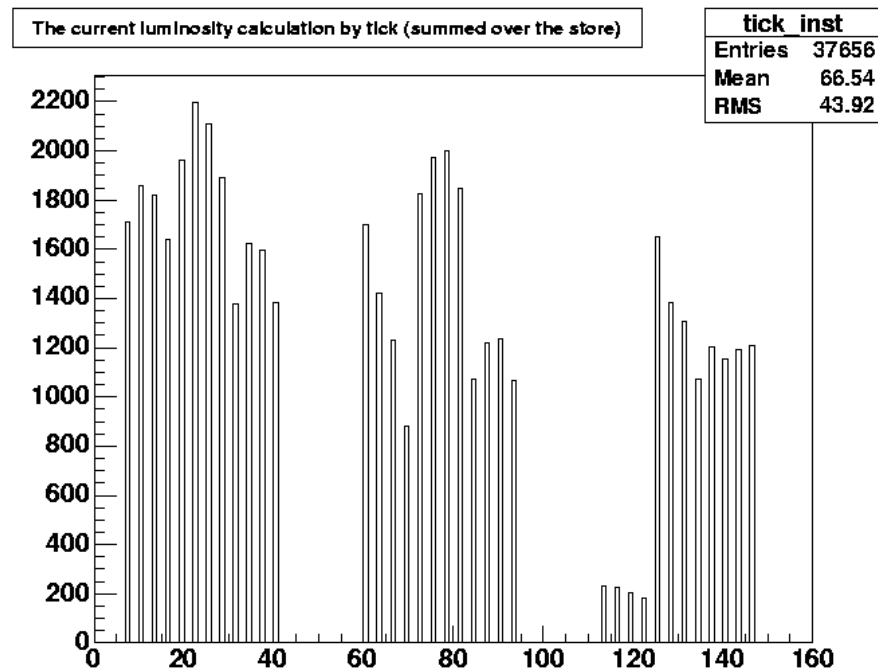
# *Is dead time caused by activation ?*

The plots show that the dead time keeps increasing through the superbunch even when the luminosity decreases. This suggests that at least part of the dead time can be due to activation. To test this we measured the counting rate during the abort gap.

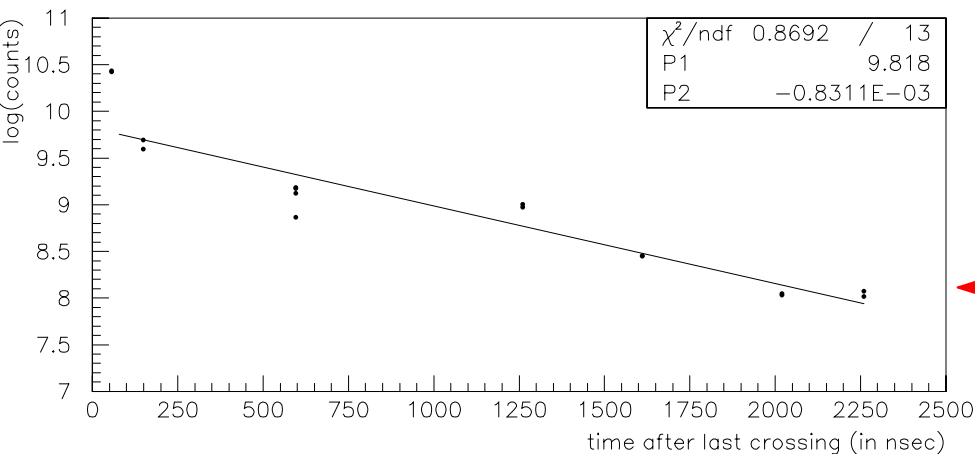
## Dead time



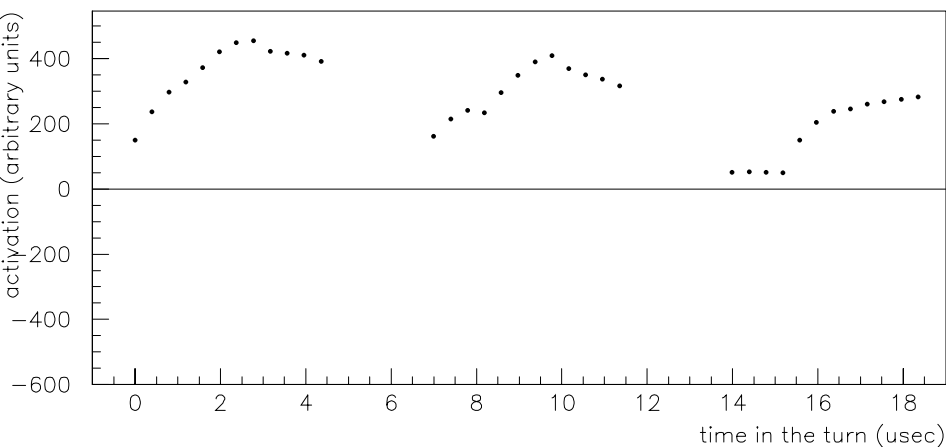
## Luminosity



# Beam activation



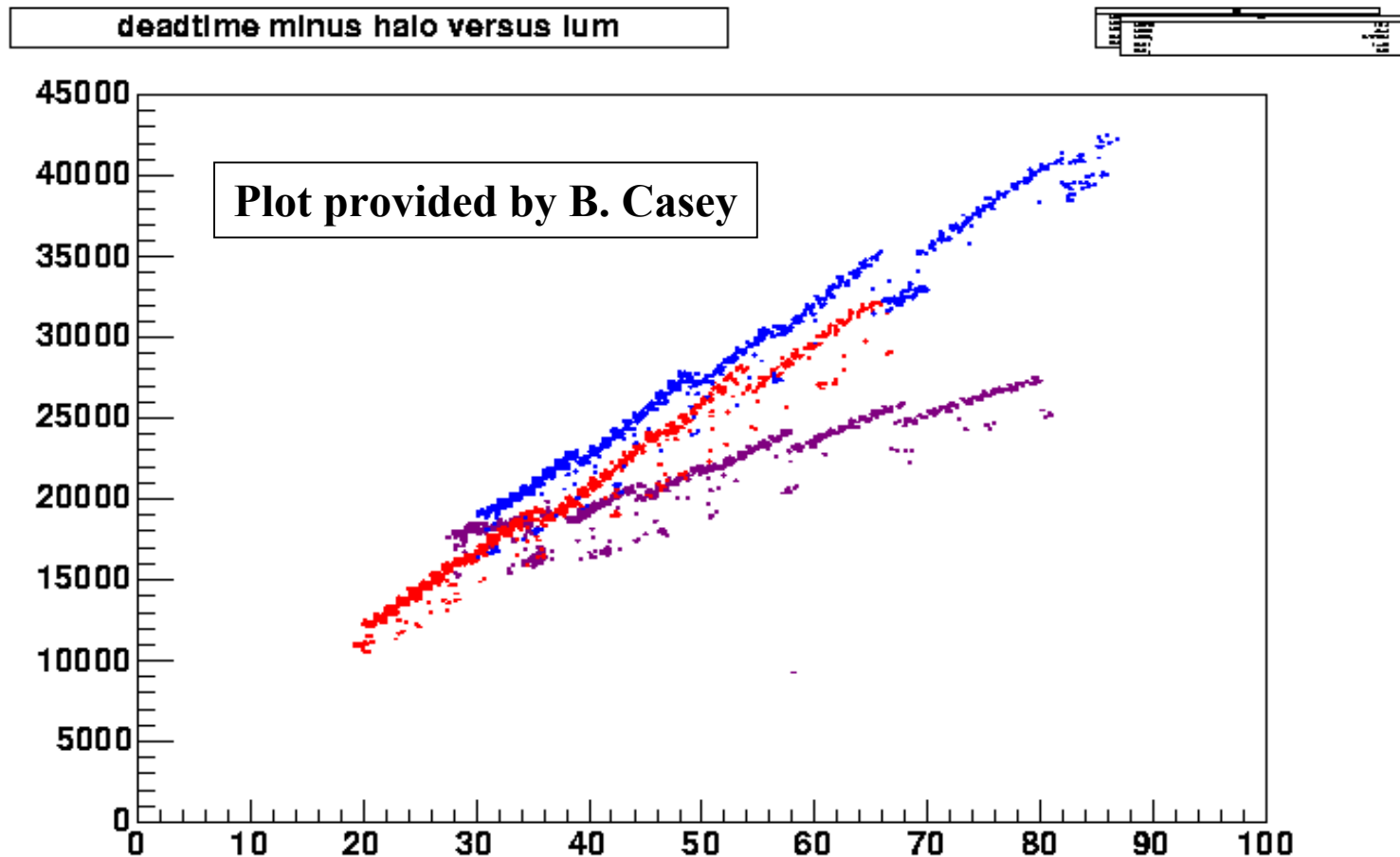
**North sum counting rate as a function of time after the 36<sup>th</sup> crossing. Gate 208 nsec. We can see an exponential decay with a decay time of 1.2  $\mu\text{sec}$**



**Simulation of the dead time produced by activation with a 1.2  $\mu\text{sec}$  decay time. The activation was assumed to be proportional to the luminosity in each tick (see plot in the previous slide). The negative scale simulates an overall constant.**



# *Dead time as a function of luminosity*



This plot demonstrate that deadtime rate minus halo rate is linear with luminosity as expected for “induced radioactivity” background.



# *Putting a discriminator in every channel*

## Appendix 4

The studies shown in the following 5 transparencies indicate that:

- A constant threshold discriminator in every channel provides worse time resolution than the current system that uses a linear sum of the analog signals.
- Using a CFD discriminator in every channel provides the same time same resolution as the current system.
- It is likely that by increasing the HV and by careful re-timing of all signals the time resolution of CFD in every channel system will improve.
- Discriminating every channel solves at least 2 problems: a) reduces the electronic noise (such as SMT noise), b) eliminates the base line shift. It also allows for the monitoring of individual channels.



# ***Discriminating every channel test***

**Two tests were performed:**

**Test 1: A Phillips 710 octal discriminator with a 10 mV threshold was used. Since we only had 5 of these modules 3 of them were used in the 1-24 north channels, and the other 2 in the south 1-16 channels. The output of the discriminators were sent to OR units forming a signal for the North detector (called N) and another for the South detector (called S). The timing of all channels was re-trimmed using 1 nsec cables.**

**Test 2: A Phillips 715 five channel CF discriminator with a 25 mV threshold was used with a 4 nsec external delay. Since we had only 3 modules we only ran 15 channels with the following arrangement: S18-S22 to mod 1, S3,S11,N3-N5 to mod 2, and N6,N8-N9,N12-N13 to mod 3. The channels were selected for their high rates. The output of the discriminators were sent to OR units forming a signal for the North detector (called N) and for the South detector (called S). The timing of all channels was re-trimmed using 1 nsec cables.**

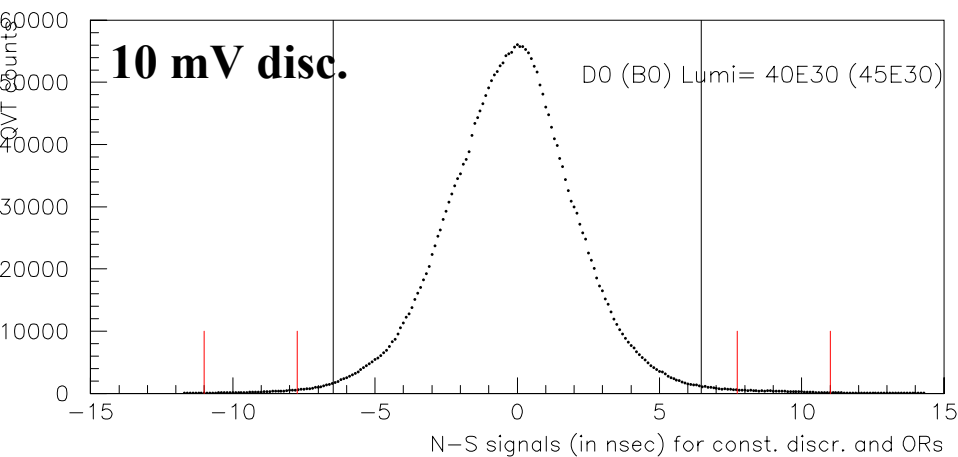
**The N and S signals were sent to a QVT. Plots with the results are shown in the following pages.**



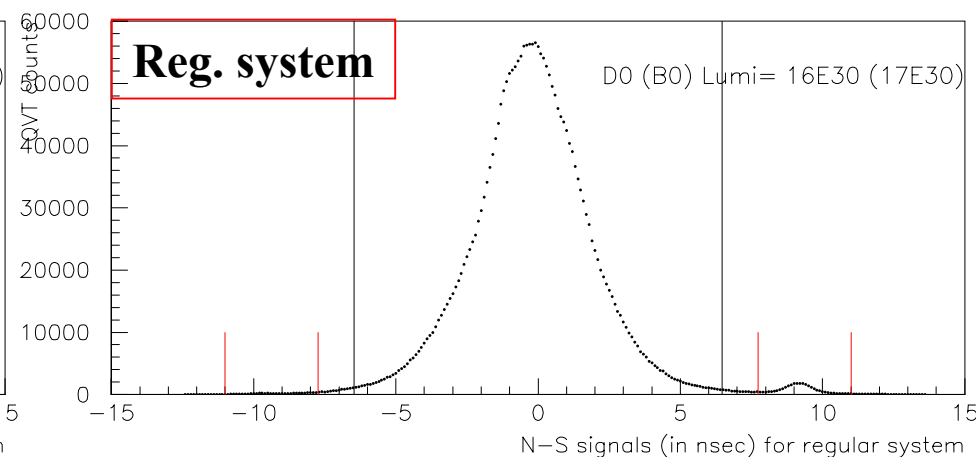
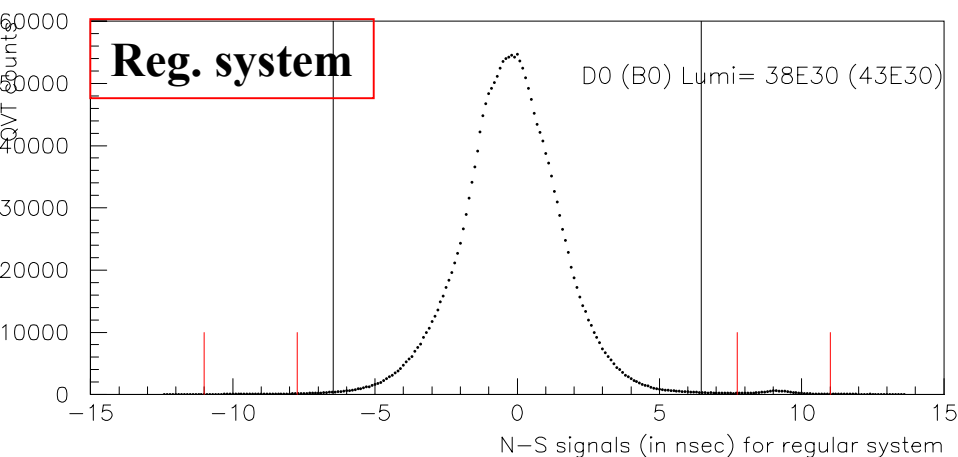
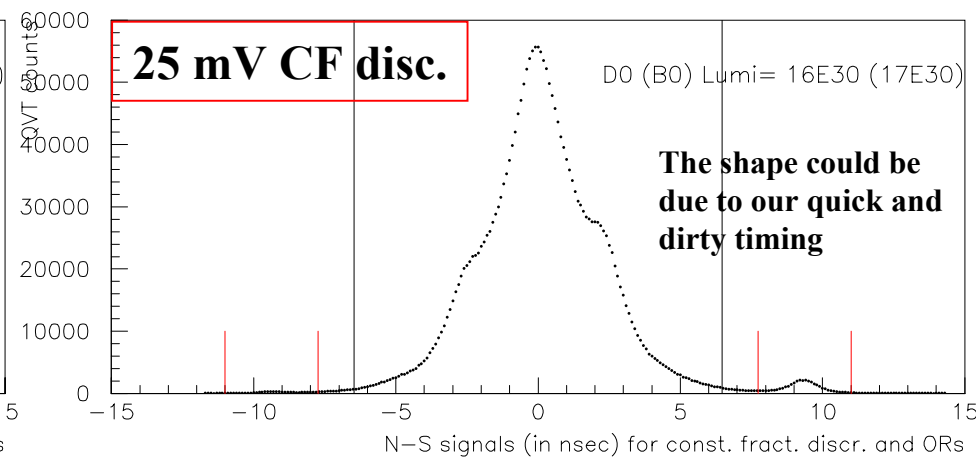
# ***QVT profiles of N-S signals***

**QVT profile of N (start) – S (stop) signals. The lines indicate the p-bar halo, Fast\_z and proton halo regions used in existing FastZ module. Top (bottom) plots peak at QVT address 207 (314).**

Store 4021, data taken 3-MAR at 20:10 (20:52) hrs for top (lower) plot



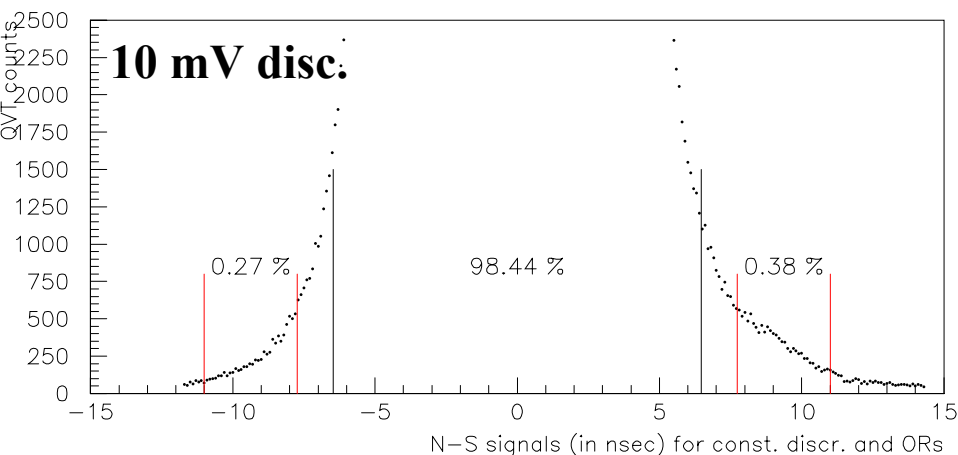
Store 4021, data taken 4-MAR at 13:30 (14:20) hrs for top (lower) plot



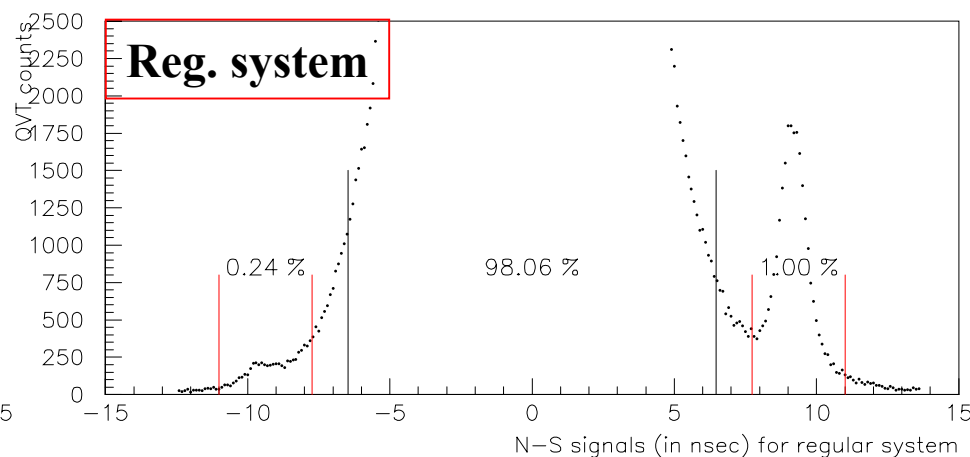
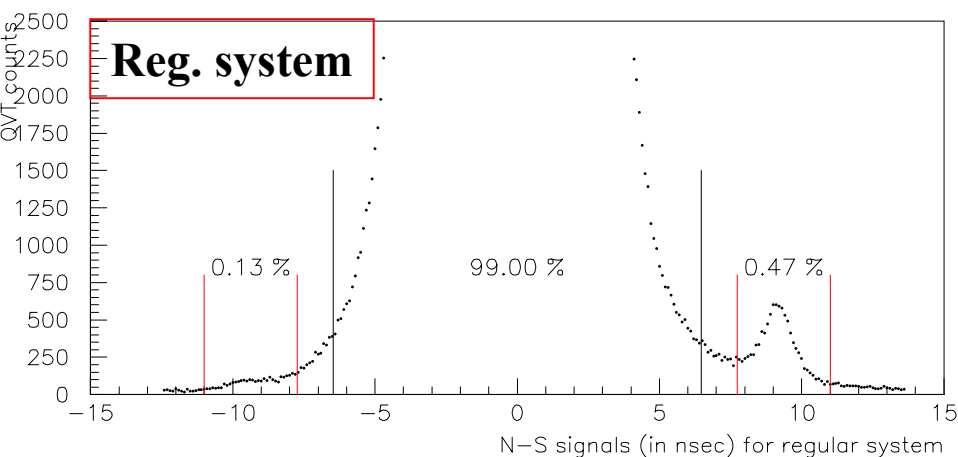
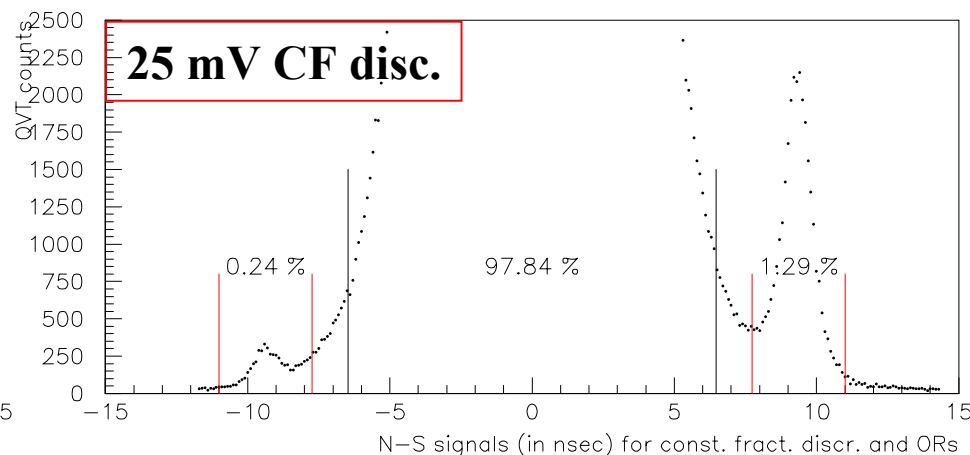
# ***QVT profiles of N-S signals***

**Same as before but on a smaller scale. The numbers in the plots indicate the fraction of the total events between the lines.**

Store 4021, data taken 3-MAR at 20:10 (20:52) hrs for top (lower) plot

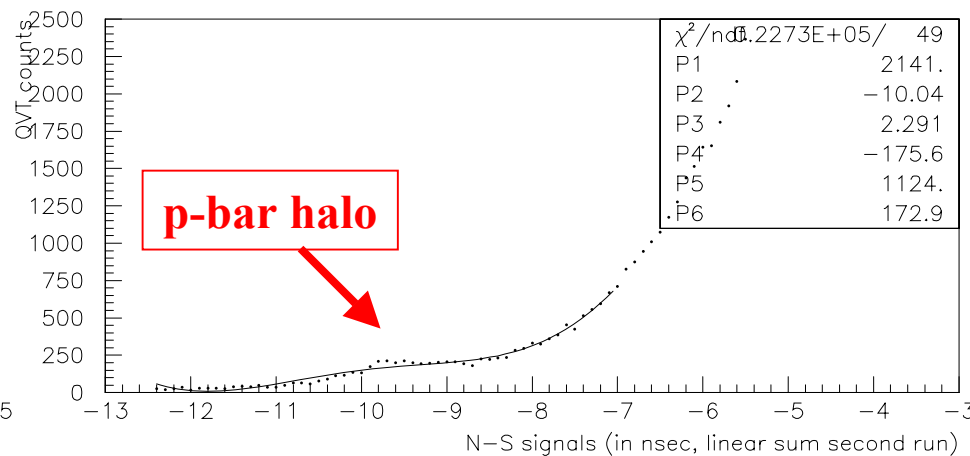
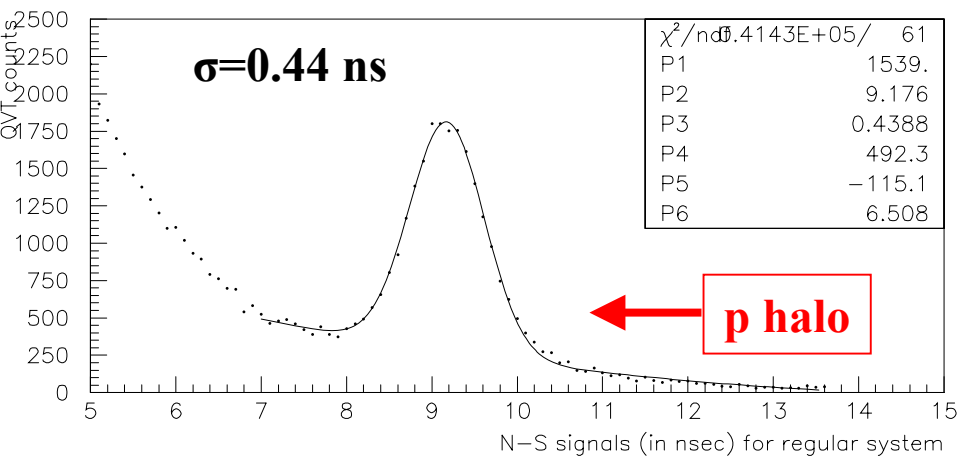
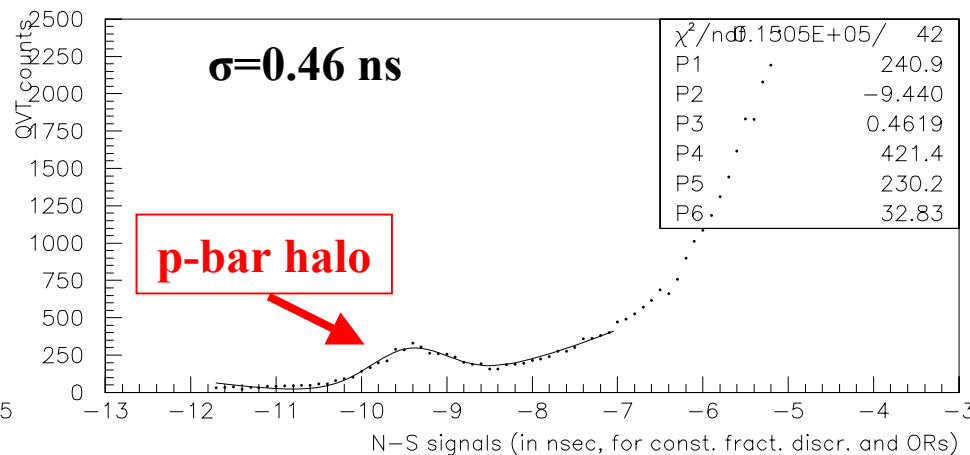
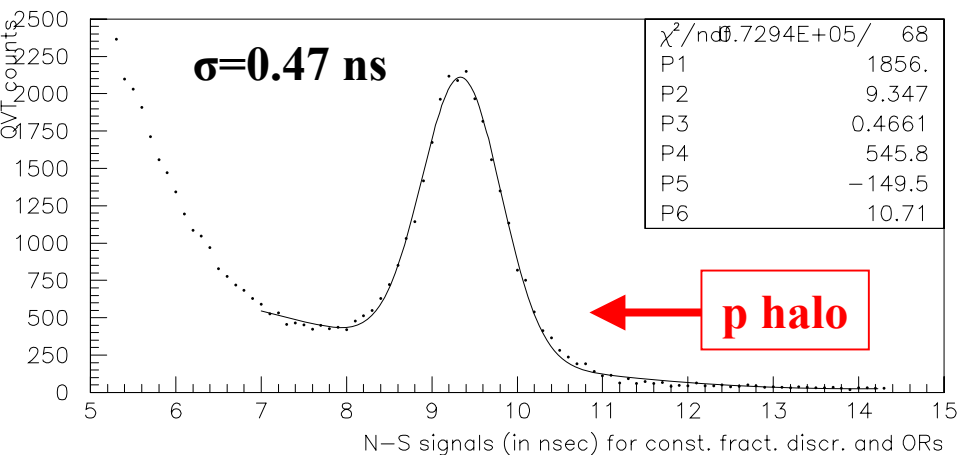


Store 4021, data taken 4-MAR at 13:30 (14:20) hrs for top (lower) plot



# Halo peaks

Top (bottom) plots correspond to the CFD discriminator (regular system) data. Part of the halo widths could be due to internal time resolution of the counters. Fit by a gaussian + parabola.



# Appendix 5

**The studies shown in the following 2 transparencies indicate that:**

- **The TFW counts FastZs correctly up to 8 digits.**
- **We also looked at the SMT noise levels and concluded that they are at the level of a 1-3 mV. The SMT noise becomes a problem when adding 24 channels.**



## ***FastZ module check***

To check the FastZ module we sent the N and S signals to the QVT as in the plots shown before, but this time we vetoed on the FastZ signal. That is the N and S signals were blocked (we used a coincidence unit to do this) when the FastZ was present. As expected there was a gap in the middle of the  $\Delta t$  (N-S) distribution. The gap was 12.2 nsec wide that corresponds to a cut of  $\pm 91.5$  cm. The difference between the edges for the inverted logic was 13.2 nsec that corresponds to  $\pm 99.0$  cm. These numbers are close to the 97 cm from D0 Note 4710.

In the gap produced by vetoing with the FastZ signals there should be zero entries. We actually saw entries at the level of  $4E-4$  at  $L=25E30$  and  $7E-4$  at  $L=70E30$ . There was some discussion that this could be due to interactions in the gaps. But we did not see a big difference when we vetoed in the abort gap. The cause of the above counts is not understood, it could be signals between crossings, the QVT misfiring, or the FastZ module, or the coincidence unit. At present luminosity levels that is not relevant, but it will be interesting to understand why it happens at it might become relevant at higher luminosities.



# ***TFW check***

**To check the TFW we counted the FastZ signals in a separate scaler. The results are shown in the following table:**

Scaler counts	TFW
11,553,676	11,553,676
12,198,965	12,198,965